3642

SOME RECENT TECHNICAL ADVANCES AND PROBABLE TRENDS IN PROCESSING, MANUFACTURE AND PACKAGING OF WHEY PRODUCTS

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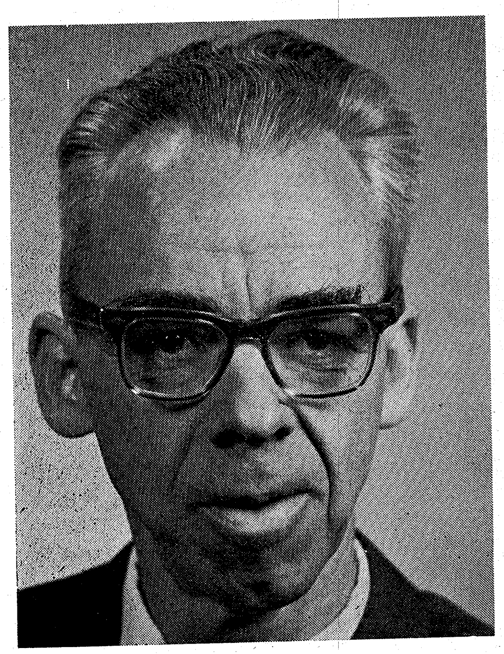

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WORLD-WIDE there is an increased awareness of the need for stopping environmental pollution caused by the dumping of whey. This, rather than a realisation of the nutritional value of whey, has accelerated efforts to utilise whey and its components in new and improved food, feed or industrial products. Whey contains half the solids of milk so that food uses, which bring the best financial return have been emphasised. The composition of whey is well-known (1) and a new study considers its nutritive value high (2). Co-precipitation processes can alter whey composition by reducing the protein but only small quantities of such whey are produced and it has not yet been recognised as a separate utilisation problem. Whey is an excellent animal feed supplement but competitive feeds are so low in price that feed uses often become distress outlets. Development of industrial products from whey, having attracted little attention for two decades may be facing a revival of research interest with Marshall's investigation of continuous lactic acid manufacture (3).

Whey processing and utilisation was the subject of two recent seminars (IDF, Germany 1969 and USDA, University of Maryland 1970) to which references will be made. Schultz (4) has thoroughly discussed whey utilisation and has reviewed the development of new whey products, especially research done at Kiel. In considering whey processing in Canada, Keay (5) finds conditions there similar to those in the U.S.

Concentration

Because of its low solids content and highly perishable nature, water removal from whey is a necessary first processing step. Vacuum condensing and drying must be used to preserve most whey in a commercially acceptable form. Design improvements continue to be made in vacuum evaporators and dryers but there have been no revolutionary changes since the last Congress. Starkie (6) working with a plate evaporator to concentrate Cheddar whey found minimal fouling conditions occurred when the protein was first coagulated by preheating to 188C for 20 minutes with acidity below pH 4·5.

In the U.S. the largest whey processors have found the double effect, upflow recompression evaporator to be most efficient (7). Whey for drying is usually heated to between 190–205F for 5–20 min to reduce bacteria counts and prevent fouling of heater surfaces (8). It is dropped from the evaporator at 50% solids and treated to crystallise the lactose by either of two methods. By one procedure the concentrate is cooled to 45F, seeded and held overnight to crystallise lactose, then quickly warmed to reduce viscosity and spray dried. By the other process the concentrated whey is seeded with lactose at pan temperature (130F) agitated in a surge tank for up to 30 min and spray dried. The lactose crystals erode the high pressure spray orifice which is renewed after about 5 hours. To obtain maximum lactose crystallisation which gives a powder of minimum moisture absorbing properties, the whey is dropped from the dryer at 12% moisture, held up to 30 min to complete lactose crystallisation, tunnel dried to 4% moisture and ground (8, 9, 10).

In Europe the multiple falling film evaporator is often used for whey concentration to 38% solids after which the whey is reduced to 60% solids in a single effect concentrator; then it is dried (7).

Acid wheys are difficult to dry but there is increasing use of foam spray drying (11). It is based on injection of air between the high pressure pump and the atomiser to obtain low density, (sp. gr. 0·1–0·4), free-flowing powders. A new whey based dispersing agent with a density of about 0·1, has been made following this procedure (8, 12). Acid casein whey is being spray dried in Australia (13).

Economics

Adverse economics has severely limited full utilisation of whey (14, 15). Most important are water removal costs, volumes available, hauling distances, the kinds of products that could be produced, uses and markets. van Allemeersch (15) presents examples of manufacturing costs to produce roller powder in a small plant of 5,000 litres of whey per hr as 4,456 FB (8·9c) per kilo dried whey. Processing costs for spray powder manufactured in 2 plants with capacities of 15,000 and 30,000 litres of whey per hour were 4,065 FB (8.17c) and 3,766 FB (7·75c) per kilo dried whey. Fixed and variable costs with all conditions as nearly comparable as possible were considered. The whey was vacuum concentrated to 40% solids before drying in every case. Production costs are thus related to plant size and this makes it almost impossible for the small cheese factory to continue to exist without an economical method of whey disposal. One solution might be to increase the efficiency of the small roller dryer by pre-concentration to 20% solids with reverse osmosis rather than to concentrate in a higher capital cost vacuum system. Heinemann (16) has discussed other alternatives.

New methods

New methods for removing water, demineralising or fractionating whey are being developed following intensive research on water desalination. Khramtsov (17) has used ion exchange resins to demineralise whey before lactose manufacture. Electrodialysis, reverse osmosis or ultrafiltration and gel filtration have passed through laboratory research and are in various stages of commercial development. However, much work remains to be done to refine the processes, increase commercial efficiency and provide profit incentives necessary to salvage the world whey supply.

Electrodialysis is used to demineralise whey by removing half or more of its salts, making possible the manufacture of a variety of products of different lactose, protein and mineral content (9, 18, 19, 20). With the development of the perm-selective membrane and equipment, processes were devised to demineralise whey before concentrating it and to remove part of its lactose, then to dry the protein concentrate (9). Efficiency was increased when whey of 25% solids was desalted (19).

Reverse osmosis

Reverse osmosis (RO) or its related technique, ultrafiltration, is a promising recent development in whey processing. Active research, published papers and commercial applications indicate the importance of this new tool for utilising whey (21, 22, 23, 24, 25, 26, 27, 28, 29, 30).

It has been shown that whey can be concentrated to over 40% solids by RO but that a practical limit is about 20–25% solids. For whey the flux or water removal rate (membrane of 75% NaCl rejection) decreases approximately logarithmically with increases in solids content of the feed product. Flux rates vary with membrane type, pressure and composition of the whey. The process is conducted at room temperature. A typical RO process might use a cellulose acetate membrane 100μ thick and of 75% salt rejection which has been bound to the inside of a strong fibreglass tube (31). Multiple tubes are used to obtain desired capacity and turbulent flow is maintained to prevent accumulation of whey solids on the membrane surface. Maximum operating pressures vary with the unit but pressures up to 800 psi are possible with some equipment.

As a means of pollution abatement RO will reduce the BOD_5 of cheese whey from 45,000 to 1,000 p.p.m. (28). A protein concentrate of the same ratio of protein, lactose and salts as skim-milk may be produced that should have multiple food uses (26, 32).

RO hardware is constantly undergoing improvement so that the processes of the future will be less costly and more efficient than they are today. Membrane life is now considered to be about 2 years. Membrane durability and porosity will surely be improved thus broadening applications and increasing the effectiveness of whey fractionation. Present costs for removing water from whey up to 10% solids appear to be less than for vacuum evaporation and the RO costs may decrease. Vacuum evaporation will be desirable and necessary to concentrate whey to solids contents beyond 25%. Reverse osmosis will occupy an important place in the future processing of whey.

Gel filtration

Gel filtration, another new tool for whey fractionation may lack the broad applications of reverse osmosis. The economics of both processes must still be resolved. Sephadex gel-filtration columns (33) can separate and remove lactose, salts and other low molecular weight constituents from the larger protein molecules of whey. Morr *et al.* (34) have described an equilibrium-diffusion process that might be applied to a large scale continuous operation to produce whey protein concentrates. This is considered superior to earlier devised batch centrifugal and column Sephadex processes. Pallansch (35) has combined parts of the procedures of Morr *et al.* (34) and of Hartman (36). Whey is treated with sodium polyphosphate and hydrochloric acid to complex the whey protein, the complex then being separated centrifugally from the lactose and salts. The protein is released from the complex by alkali treatment and separated by Sephadex. The dried concentrate contains up to 80% undenatured whey protein. Commercial applications for separation of whey protein by use of Sephadex or other resinous, porous material must wait further development.

Animal feeds

From the beginning man concluded that the cheese he made was a better food than the whey which was discarded or fed to animals. Although we lack firm figures, in the U.S. we are probably utilising from a third to a half of the 22 billion pounds of whey we produce and about 75% of this is used for animal feed. Some is fed as a liquid, some is concentrated for mixing with other feed or used as whey blocks, but increasingly whey is being dried for a feed ingredient. Preservation of whey with peroxide before drying does not adversely affect its feed value (37). Dried whey sells for 3½ to 4½ cents per lb in the U.S., barely the production cost. We will continue to use whey as a feed but its nutritional value in combination with other feeds when used for each species of animal must be more accurately determined. This is necessary so that whey handlers and processors will obtain a reasonable return and the whey will be efficiently utilised.

Recent work on the use of whey as a feed for calves, cows and pigs has been reviewed by Ternouth (38). For maximum value whey must be supplemented with other feed ingredients to adjust the nutrients to the needs of animal age and species. Ternouth predicts that with a better understanding of whey composition in relation to digestive capabilities of different animals the use of whey and non-milk proteins for young animals and whey plus grain meals for older animals will increase. In considering mixtures, skim-milk produces better gains than mixtures of whey with meat, fish or soy meals but costs often are greater for the milk.

Fermentation

Whey can be improved as an animal feed by utilising lactose fermenting yeasts. In his review "Fermentation Products from Whey" Marth (39) reports *Saccharomyces fragilis* to be the organism of choice for producing yeast and Chapman (40) in a new study has outlined optimum yeast recovery conditions. Blanchet and Biju-Duval (41) and Mayer (42) describe commercial processes for production of food and feed yeast but actual food uses appear slight because most persons dislike yeast flavour. A well-balanced fodder was produced by Bednarski and co-workers (43) by first fermenting all the lactose in a fortified continuously-limed medium with bacteria, then adding cooked potatoes and mold culture.

Fermentation of whey has long been used to prepare alcohol, vinegar and lactic acid. The lactose of whey was the substrate for penicillin manufacture and microbiologists are constantly looking for other new and unique fermentations from whey especially in pharmaceuticals. No new break-throughs can be reported during the last four years.

Lactose

The preparation of lactose in useful form and the development of markets for both lactose and dried whey are important in the scheme of whey utilisation. Research on lactose has been reviewed by Nickerson (44). The effect of additives on crystal growth rates has been studied (45). Lactose produced in New Zealand and in Europe is made from both cheese and casein wheys while only cheese whey is used to manufacture lactose in the U.S. New manufacturing procedures using cheese whey have been devised in the U.A.R. (46).

The presence of lactose in dairy products has presented analytical problems in the determination of its water of crystallisation. DeMoor and Hendrickx (47) confirming earlier work found that of four common procedures the Karl Fischer method was most satisfactory for determining total water content in all kinds of dry whey samples. Berlin and co-workers (48, 49, 50) in basic studies of water sorption in dairy products have shown that lactose crystallisation plays a significant role in the sorption process. There is substantial mobility of sorbed water at relative humidities of 20–50% due to an initial water–protein binding followed by lactose solubilisation and crystallisation at increased humidities. Binding of water by milk salts below 50% relative humidity is essentially zero but as humidity increases above 50% the salts bind water rapidly and extensively.

Whey protein

Whey protein is easily recovered by heat for use in food or feed. The newer tools for preparing soluble protein, reverse osmosis, electrodialysis and gel filtration have been discussed. Heat coagulation will clarify whey for lactose manufacture, prepare co-precipitates and separate insoluble whey protein. Guy *et al.* (51) observed that in high-calcium cottage cheese whey the protein was more readily heat precipitated when the pH was adjusted upward. Roeper (52) precipitated 70–80% of the heat denaturable proteins from wheys by heating them to 85C for 10 min under different conditions (pH 5·9–7·5 and calcium 500–2,000 p.p.m.). Extent of protein precipitation to 80% was related to the level of soluble calcium in the whey. For maximum protein precipitation soluble Ca had to be increased with increases in pH. Morr (53) produced total whey protein denaturation in pH 4·6 whey systems by heating to 90C for 10 min. Recent protein research in Australia including whey protein and co-precipitate work is being reviewed by Rice (54).

Food uses

Processes for converting whey into food grade materials are now known but the challenge of the 70's will be how to find profitable food uses for all the whey that can be prepared. Many combinations of whey and milk components have been proposed and used for food manufacture. One promising whey preparation is a reverse osmosis fractionated whey of the same protein, lactose and salt composition as skim-milk but with replacement of casein by whey protein (25, 32). This undenatured protein product should have unique whipping and water binding properties not found in skim-milk.

Acid wheys may be used as a means of introducing acid into food products, in place of citric, phosphoric or lactic acids. Kosikowski (55) has used acid whey powder to directly acidify milk in the manufacture of cheeses including cottage and Mozzarella. Acid whey can be used as a beverage base when mixed with fruit juice or in whey sherbets and water ices.

The use of whey in bakery goods, confections, frozen desserts and specialty foods has been discussed in various chapters of Byproducts From Milk (1).

Packaging

Gradual improvements have been made in whey containers and packaging for feed and food. Bulk storage of whey at the processing plant was successful when it was held in fibreglass polyester reinforced plastic tanks (56). Since dry whey is not a consumer item it is customarily sold in the U.S. in 50 or 100 lb multiwall bags. For feed the elastic multiwall paper bag with a polyethylene barrier spot pasted at the top is used. Food packages employ a somewhat heavier bag and liner with white outside and of 50 lb capacity for ease of handling. In filling equipment there is a trend from the open sock-type filler and sewn bags to the enclosed valve-type filler and bag (57). With increases in highly automated feed mills, handling of dried whey in bulk hopper cars and trucks, thus eliminating individual packaging, is gaining in popularity.

Whey has been suggested as a binder ingredient for making polyurethane foam (58).

The future

Eventually most of the world whey supply will be processed for use in food or feed and that not so used will be discarded into approved treatment systems. In the U.S. this could occur by 1974. Advanced processing techniques for preparing new forms of whey and new whey foods will soon be ready for commercial exploitation. Studies must be conducted to explore and define the increased nutritional quality of foods and feeds when combined with whey products. Basic studies should be made to determine whether any whey components have nutritionally undiscovered functional properties. The usefulness of new whey-grain combinations for food and feed should be explored. The question of lactose intolerance must be resolved and the value of lactase to make hydrolyzed foods or feeds determined. We know now how to stop the waste of whey but continued effort must be expended to make our processes and uses more economically attractive and to develop markets (59).

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MINI REPORT — MINI RAPPORT — KURZBERICHT

Mini Report—A.4.10—Some recent technical advances and probable trends in processing, manufacture and packaging of whey products

THE LECTURER referred to the world-wide trend to prevent environmental pollution caused by the dumping of whey. This, rather than a realisation of the nutritional value of whey, has accelerated efforts to develop food, animal feed and industrial uses for whey. Whey contains half the solids of milk and has a high nutritive value.

There have been few developments in the conventional evaporators and dryers used for the drying of whey and production costs are still very high. However, new methods for removing water are under investigation and electrodialysis, reverse osmosis or ultra filtration, and gel filtration are being developed commercially.

Electrodialysis is used to demineralise whey by removing half or more of its salts thus making possible the manufacture of a variety of products of different lactose, protein and mineral content.

Reverse osmosis is a very promising development which allows whey to be concentrated to over 40% solids but the practical limit is about 20–25% solids. The process will reduce the B.O.D. of cheese whey from 45,000 to 1,000 p.p.m. A protein concentrate with the same ratio of protein, lactose and salts as skim milk may be produced, and this should have multiple food uses because of its unique whipping and water-binding properties not found in skim milk. The present costs for removing water from whey up to 10% solids appear less than for vacuum evaporation, but evaporation will be necessary to concentrate whey to beyond 25% solids. Reverse osmosis will be important in the future processing of whey.

Gel filtration may lack the broad applications of reverse osmosis.

In the United States about 33–50% of the 22 billion pounds of whey are utilised, about 75% being for animal feed. The dried whey sells for 3½ to 4½ cents per pound in the United States and this barely covers the production cost.

For maximum value, whey for animal feed must be supplemented with other feed ingredients to adjust the nutrients to the needs of the animal. Whey can be improved as an animal feed by utilising lactose-fermenting yeasts, but this approach would not increase food uses because most persons dislike yeast flavour. Wheys may be used also for producing lactose and lactic acid.

Processes for converting whey into food-grade materials are now known, but the challenge of the 70's will be to find profitable food uses for all the whey that can be prepared.

Mini Rapport—A.4.10—Quelques progrès techniques récents et évolution probable de la transformation, fabrication et emballage des produits à base de sérum

LE CONFERENCIER a pris comme sujet l'évolution mondiale pour la prévention de pollution environnante occasionnée par le déversement de sérum. Ce fait, plutôt que la réalisation de la valeur nutritive du sérum, a accéléré les efforts dans le développement de l'alimentation, l'alimentation pour animaux et l'emploi du sérum dans l'industrie. Le sérum contient une moitié des solides du lait et a une valeur nutritive très élevée.

Il y a eu peu de développements dans les évaporateurs et séchoirs conventionnels utilisés pour le séchage du sérum et les coûts de productions sont encore très élevés. Toutefois, de nouvelles méthodes pour l'évaporation de l'eau sont à l'étude et l'électrodialyse, l'osmose inverse ou ultra filtration et filtration de gel sont à l'état de développement commercial à l'heure actuelle.

L'électrodialyse est utilisé pour déminéraliser le sérum en ôtant la moitié ou plus des sels, rendant ainsi la fabrication d'une variété de produits contenant une dose différente de lactose, protéine et minéraux.

L'osmose inverse est un développement qui promet et qui permet au sérum d'être concentré à plus de 40% de solides mais la limite pratique est d'environ 20–25% de solides. Le procédé réduira la demande Biologique-Oxygène du fromage de sérum de 45.000 à 1.000 p.p.m. Un concentré de protéine avec le même taux de protéine, lactose et sels que de lait écrémé peut être fabriqué, et devrait avoir plusieurs emplois alimentaires à cause de son fouettage unique et propriétés agglomérantes pas retrouvés dans du lait écrémé. Les coûts actuels pour extraire l'eau du sérum contenant jusqu'à 10% de solides apparaissent moins élevés que pour l'évaporation par aspiration, mais l'évaporation nécessitera une concentration du sérum dépassant 25% de solides. L'osmose inverse sera important dans la transformation future du serum. Les larges applications de l'osmise inverse peuvent faire defaut à la filtration de la gelée. Aux Etats-Unis, environ 33–50% des 22 billion de livres de sérum sont utilisés, environ 75% étant pour l'alimentation animale. Les sérums séchés se vendent de 3½ à 4½ cents par livre aux Etats-Unis et ceci couvre à peine le coût de production.

Pour obtenir un rendement maximum, le sérum pour l'alimentation des animaux doit être complété par d'autres ingrédients alimentaires afin d'ajuster les éléments nutritifs aux besoins de l'animal. Le sérum peut être amélioré comme alimentation animale en utilisant de la lactose fermentée par levure, mais cette mesure n'augmenterait pas l'usage alimentaire car la plupart des personnes n'aiment pas le goût de la levure. Les serums peuvent aussi être utilisés pour la production de lactose et acide lactic.

Les procédés utilisés pour convertir le sérum en matériel de grade alimentaire sont maintenant connus, mais dans les années 70 le challenge sera de trouver des utilisations alimentaires profitables pour tout le sérum pouvant être préparé.

Après une brève ouverture par Mr. O. E. Lenau (Danemark) une discussion animée s'ensuivait, laquelle concernait principalement les aspects techniques et économiques de la concentration du sérum par osmose inverse. Les propriétés de nutrition des protéines et lactose du sérum étaient également discutées et la nécessité de recherches supplémentaires était notée.

Kurzbericht—A.4.10—Neueste technische Fortschritte und mutmassliche Richtungen bei der Bearbeitung, Herstellung und Verpackung von Molkenerzeugnissen.

DER VORTRAGENDE verwies auf die über die ganze Welt verbreiteten Bestrebungen, Maßnahmen zu treffen, um eine Verunreinigung der Umgebung durch Abladung von Molke zu verhindern. Dies war es auch—und nicht so sehr die Erkenntnis des Nährwertes der Molke—was dazu geführt hat, dass man sich eifriger bemüht, die Verwendung der Molke als Nahrungsmittel, Tierfutter und für industrielle Zwecke auszugestalten. Die Hälfte der Festbestandteile der Milch sind in der Molke enthalten, welche daher einen hohen Nährwert hat.

Bei den zum Trocknen der Molke verwendeten konventionellen Verdunstern und Trocknern waren nur geringe Fortschritte zu verzeichnen und die Produktionskosten sind noch immer sehr hoch. Doch werden neue Methoden der Wasserentziehung untersucht und die Elektro-Dialyse, die rückläufige Osmose oder Ultra-Filtrierung und die Gel-Filtrierung werden auf eine kommerzielle Grundlage gestellt.

Die Elektro-Dialyse wird angewandt, damit die Molke weniger Minerale enthält. Dies geschieht, indem man die Hälfte oder noch mehr der Salze entfernt, wodurch es möglich wird, verschiedenartige Produkte mit unterschiedlichem Laktose-, Protein- und Mineralgehalt zu erzeugen.

Die rückläufige Osmose verspricht viel. Man kann durch sie die Molke bis zu über 40% Feststoffen konzentrieren, aber die von der Praxis gezogene Grenze ist etwa 20 bis 25% Feststoffe. Dieses Verfahren verringert den biologischen Sauerstoffbedarf der Käsemolke von 45.000 auf 1000 p.p.m. Man kann ein Proteinkonzentrat herstellen, das den gleichen Anteil an Protein, Laktose und Salzen hat, wie Magermilch, und das in mehrfacher Weise als Nahrung verwendet werden könnte, wegen seiner ganz besonderen Fähigkeit, zu schlagen und Wasser zu binden, die bei der Magermilch nicht anzutreffen ist. Die gegenwärtigen Kosten des Wasserentzuges aus der Molke in dem Ausmaß, dass die festen Bestandteile schließlich 10% ausmachen, scheinen geringer zu sein, als die Kosten der Vakuumverdunstung, aber Verdunstung wird notwendig sein, wenn man die Molke so konzentriert haben will, dass die festen Bestandteile mehr als 25% ausmachen. Für die Verarbeitung der Molke in der Zukunft wird die rückläufige Osmose eine wichtige Rolle spielen.

Gel-Filtrierung hat wohl nicht ein so weites Anwendungsgebiet, wie rückläufige Osmose. In den Vereinigten Staaten werden ungefahr 33 bis 50% der 22 Milliarden Pfund Molke nutzbar gemacht, davon 75% für Tierfütterung. Getrocknete Molke wird in U.S.A. um 3½ bis 4½ Cents das Pfund verkauft und das deckt kaum die Herstellungskosten.

Um den höchsten Wert als Tierfutter zu erzielen, muss man die Molke durch andere Nahrungsbestandteile ergänzen, um die Nährstoffe den Erfordernissen des Tieres anzupassen. Molke kann als Tierfutter verbessert werden, indem man von Laktose-Gärungshefen Gebrauch macht, doch ihre Verwendung als Nahrungsmittel für den Menschen kann dadurch nicht gesteigert werden, denn die meisten Menschen haben eine Abneigung gegen den Hefegeschmack.

Molken können ebenfalls zur Erzeugung von Laktose und Milchsäure verwendet werden.

Es sind schon Verfahren bekannt, durch die man Molke in nahrhafte Substanzen umwandeln kann, aber die Aufgabe der Siebzigerjahre wird es sein, eine einträgliche Verwendung als Nahrungsmittel für alle die Molke zu finden, die zur Verfügung gestellt werden kann.

DISCUSSION

O. E. Lenau, *Denmark*. I would like to congratulate you, Dr. Webb, on a most interesting paper. If the question of pollution and contamination by whey dumping has brought us around to thinking in terms of utilisation of whey in a better manner than has been done so far, then I can consider we are lucky. I noticed particularly that you mentioned a figure which, to me, was staggering. You said that you had a production of whey in the U.S. of about 22 billion pounds a year of which you effectively utilise one-third. Now today in the world the question of protein supply is a major problem, and surely a lot of protein must have been lost in the other two-thirds of the whey.

Another point of great interest to me is the various new methods which have been introduced lately, and as you also mentioned there had not been much movement and much progress for about a couple of decades in the utilisation of whey. You were referring to ion-exchange processes, to electrolytic processing, to gel-filtration and to reverse osmosis. As this topic, in my opinion, is of world-wide interest, I would like to conclude my contribution by expressing the hope that "with it" discussion will emerge from Dr. Webb's most interesting paper. I am particularly thinking of the possibility of combining these various new methods for utilising the enormous quantity of whey which is at disposal at the moment and which will increase.

J. L. Maubois, *France*. Professor Webb told us that the practical limit for concentration of whey by reverse osmosis is 20% total dry matter. Could Professor Webb tell us what the technological or economic criteria are that lead him to make this statement?

B. H. Webb, *U.S.A.* The limiting factor here is what you can get through the membrane without clogging it up. Now, as whey increases in concentration, your proteins increase, your lactose increases in concentration and when you get up to about 20% or so, it is increasingly difficult to get water through the membrane. This, as I mentioned, is an exponential change with concentration. It is really most practical if you stay below 10% solids, and then do the rest of your concentrating in a vacuum evaporator. What we had thought would be a practical thing in the U.S. would be for those small cheese factories that cannot afford expensive vacuum evaporating equipment to instal reverse osmosis equipment, which is cheaper, and to take out 60–80% of the water getting to 20% or so solids, and then put it in a truck and haul it to a processing plant. The cost of hauling then would be greatly reduced and would cover probably, we think, the cost of reverse osmosis treatment. These things are still in a state of investigation, and there really is no commercial experience.

M. Naudts, *Belgium*. I would like to ask Dr. Webb what he thinks about the extent of heating that whey can undergo without this affecting the nutritional value of the protein in the whey.

B. H. Webb, *U.S.A.* I do not know that we have really good answers. Of course we know that heating to 80C or so will precipitate most of the proteins, depending upon the salts present and on a number of factors, such as time. This certainly changes the physical characteristics of the protein and limits the things that you can do with it in preparing food. As far as the nutritional value is concerned, I think this is generally considered not to affect it very seriously. Certainly the amino acid balance and the critical things are unchanged. But as for the growth-promoting factors that might be there and might be changed, I don't believe that we can answer at this point. I would say in general though that the heat treatment does not very seriously affect the nutritional value.

K. H. Farrer, *Australia*. I understand that the sanitation of membranes is a major problem in the preparation of food products by reverse osmosis. Could Dr. Webb comment on this please?

B. H. Webb, *U.S.A.* We have done some work in the dairy products laboratory on the sanitation of membranes. We apparently have had less trouble than some other people. We have not been bothered by coating on the membrane and I gather from talking to some others in various research stations that they have had some coating. This may be because they have operated for a longer time. Our experimental work has been limited to about 8 or 10 hour runs. During this period we have had no serious coating on the membranes. That being the case, we have simply flushed them out. Of course you have to keep them wet all the time. We have used various iodophor sanitisers. Part of this work is completed and written up for publication and will be published very shortly. I perhaps should add that we feel that the sanitation part of it can be taken care of, that you can operate on a food sanitation basis. There are some changes that may be necessary in the hardware of the unit, of the units that we have now, and we have drawn up specifications for what we feel would be a good unit. This has to be manufactured shortly in the States and we are expecting to obtain commercial experience with this unit.

G. Mocquot, *France*. I understood Professor Webb to say that the cost of reverse osmosis was going to increase. Could Professor Webb say if that is indeed the case or if I misunderstood?

B. H. Webb, *U.S.A.* I did not mean to say that it was going to increase. We hope it is going to decrease. We hope that this will happen as we get the hardware improved and as new membranes are developed that might have longer life (and we really don't know at this point how long these membranes will last, we are saying two years). We have had membranes in the laboratory that have operated for two years and they are alright although they are decreasing in efficiency during this time. But how often we will have to renew the membranes we don't know at this point. The people who are making membranes seem to confidently expect to make better ones. This will reduce costs. I think we have every reason to believe that there will be a cost reduction here. How much I would not hazard a guess but I think that there will be a reduction as we gain more experience.

R. A. Buchanan, *Australia.* Dr. Webb, can you tell us if you know of any work to show nutritional advantages for human or animal feeding for lactose compared to other carbohydrates?

B. H. Webb, *U.S.A.* Well, some people think there are nutritional disadvantages. We have had this lactose intolerance problem for some time, which not all of us quite believe is as serious as some of the experimental work seems to indicate, especially when they feed as much lactose as they have been doing in those experiments. But as to a nutritional advantage for lactose, well, of course in the infant certainly apparently it is necessary; there is a connection with calcium metabolism, we feel. As far as adults are concerned, perhaps we need to do more work. I do not think I can answer that one. If you can metabolise the sugar, you get the energy. If you cannot, you get adverse effects, but nutritionally maybe we should go to work and see if we cannot find more advantages than those we know.

J. W. Claessons, *South Africa.* I was rather interested in the speaker's reference to plants that are being developed in the United States for reverse osmosis. I was wondering if, perhaps, he could tell us in what capacities these would come, because he mentioned that there is a possibility there for the smaller cheese factories to preconcentrate the whey for further treatment at larger units.

B. H. Webb, *U.S.A.* We have a very small unit at the laboratory; it happens to be a Haven's unit. However, the commercial unit that we have drawn plans for and is in the process of being built, will handle about 100,000 lb. of whey in about 20 hours. Now, this is all just a matter of adding multiple units, so you can get about any size that you wish to have. If the cheese factory is only producing 30, 40 or 50,000 lb. of whey per day, then it would just be a small unit and these should be, of course, less expensive because there are fewer modules. So, I guess the answer is you can have any size unit to accommodate the whey of about any size cheese plant. The plants that we have had especially in mind in the United States are those producing less than 100,000 lb. a day. We feel that if they are producing 100,000 lb. a day or more, they can perhaps afford to put in condensing equipment and go all the way in concentrating the whey; but for the smaller ones of lesser output, then we feel the reverse osmosis unit with the number of modules tailored to the production of the plant, would be the most practical. Of course, you can save your whey and have a fairly small unit and just run it 24 hours or 20 hours.

A. Eck, *France.* In the United States, what do the Public Health Authorities feel about these new methods? What attitude do they adopt towards them?

B. H. Webb, *U.S.A.* I think we are a little ahead of them. As far as I know, there has not been much appraisal of reverse osmosis units as to public health aspects of sanitation and what might be required. For instance, we have this 3A Sanitary Standard Committee and they have not even been asked to look at reverse osmosis units yet. The thing is too new. We have to get the hardware fixed up; we have to get it designed and made as best we can for food uses and then they will take a look at it and tell us what more we have to do.

J. Mol, *Holland.* In some countries, Dr. Webb, some sodium nitrate is added to the cheese milk in order to prevent butyric acid fermentation of the cheese. Most of the sodium nitrate will get into the whey, of course. I should like to ask you whether this is also the practice in the United States and if so, if this presence of sodium nitrate is in your opinion perhaps objectionable for use in human food?

B. H. Webb, *U.S.A.* No, I guess I do not have any particular opinion about that. With a reverse osmosis unit, if you select your membranes you should be able to get rid of these salts if they are going to be undesirable. We have done quite a little work with our cottage cheese whey, which is quite acid. We can remove the acid and some of the salts with it. At the present time, using membranes in removing the acid, we get quite a little lactose too, but there is a very wide range of possibilities as to the membranes that can be developed. So I would expect that if any of the salts are undesirable we would be able to take them out. Now there is an expense matter here too, so you have to consider whether it is going to be economic to do this. Whey is a pretty cheap commodity and you cannot get much for it, so we are going to be limited as to how much money we can put in to process it.

G. A. Dummett, *United Kingdom.* I would like to ask Professor Webb whether he could express an opinion to us on the relative importance of reverse osmosis as compared with electrodialysis for whey treatment now and in the future?

B. H. Webb, *U.S.A.* Electrodialysis got started much earlier, as you know. It is a going commercial process. It is a little on the expensive side. Personally, I think after we have had as much experience with reverse osmosis as there is with electrodialysis, the reverse osmosis will be cheaper. As I understand it, the electrodialysis product is pretty expensive, and I hope that we will be able to process whey by reverse osmosis and keep the processed product much below the cost of the electrodialysed product. Many of these things must still be resolved.